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Microcomputer-Based Monitoring and Control System With Uranium Mining Application

By C. T. Sheeran and J. C. Franklin

UNITED STATES DEPARTMENT OF THE INTERIOR

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UNITED STATES DEPARTMENT OF THE INTERIOR
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BUREAU OF MINES
Robert C. Horton, Director

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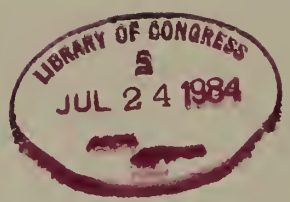

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UNIT OF MEASURE ABBREVIATIONS USED IN THIS REPORT

ft/min	foot per minute	min	minute
h	hour	ms	millisecond
in	inch	pct	percent
kHz	kilohertz	s	second
km	kilometer	V ac	volt, alternating current
L	liter	V dc	volt, direct current
m	meter	WL	working level
MeV	million electron volts	WLM	working level month

MICROCOMPUTER-BASED MONITORING AND CONTROL SYSTEM WITH URANIUM MINING APPLICATION

By C. T. Sheeran [1] and J. C. Franklin [2]

ABSTRACT

The Bureau of Mines investigated a microprocessor-based real-time control and monitoring system for uranium mining applications. The system is capable of controlling and monitoring up to 768 stations within 3 km of the central processor on a common four-wire cable. It can be used in conjunction with detectors to continuously monitor and display radiation working levels at points throughout the mine. Surface alarms are sounded for critical situations such as rapid radiation buildup, loss of power to monitors or fans, and changes in air door position. Permanent records of all changes are automatically printed out with their time of occurrence. Printouts can also be obtained for shift reports or trend logs. The system can be used to remotely control fan startup and shutdown, and also can alert miners of underground conditions by blowing horns or turning on lights. Battery backup keeps the system operative for up to 4 h in case of a mine power outage. A special software feature permits automatic, time-delayed, sequential restart of fans.

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INTRODUCTION

In protecting the health and safety of underground personnel, the mining industry must contend with the radioactive gas radon and its daughter products. Radon and radon daughters are decay products of uranium and are found in nearly all types of mines. However, the extreme concentrations of these daughters in uranium mines present a greater health hazard than that found in other types of mines.

The radon daughters polonium-218 and polonium-214 emit alpha particle radiation that may induce certain forms of cancer. Exposure to these daughters in mine air has been shown to produce a high incidence of lung cancer among uranium miners (1).[3] Present Federal safety standards state that the maximum allowable concentration of radon daughters in a work environment is 1 WL unless respirators are worn. Total exposure per person is limited to 4 WLM for any calender year.[4]

Most of the uranium produced in the United States is mined from sandstone formations, which have high porosity and permeability and which may be highly fractured. Because of this, radon is released from the sandstone very readily, and its emanation rate can be profoundly increased by a slight decrease in barometric pressure.

Ventilation techniques that employ blowing, exhausting, and push-pull fan combinations are used by the industry to supply adequate air quantities to reduce the radon daughter concentrations. As uranium mines have become larger and deeper, and electrical costs have risen, ventilation costs have increased sharply--ventilation now accounts for a major portion of underground uranium mine production expenditures. Bates (2) estimated that in order to comply with the 4-WLM standard, these costs ranged from $4.68 to $5.41 per ton of ore removed in 1980. This estimate included costs for electricity, ventilation shafts, fans, vent bags, and other associated equipment.

An interruption in mine power, causing fan shutdowns, can produce drastic changes in the radon and radon daughter concentrations. Sometimes shutdowns may go undetected for some time. Franklin (3) and Musulin (4-5) have shown that fan shutdowns of 5- to 30-min duration can increase radon concentration to three to five times normal. Franklin (6) reports that the mining activities of slushing and blasting may increase this concentration up to 40 and 400 pct, respectively.

The uranium industry presently uses Kusnetz sampling to determine personnel exposure and to detect areas where ventilation changes are needed to maintain desirable radon daughter levels. These samples are taken at various intervals ranging from daily to monthly, depending on radiation concentration and sampler availability. Kusnetz-type samples are usually very accurate point-in-time measurements. However, since concentrations are continually changing, more continuous methods of monitoring are needed to minimize miner exposure. Continuous monitoring can provide data never before available to ventilation engineers, which can be used to optimize the ventilation network.

The Bureau of Mines has been investigating instrumentation that can help in detecting excessive working levels. Droullard (7) devised a continuous working level monitor that has been used for several years in the Bureau's research activities in both experimental and active mines. Shaw and Franklin (8) took this continuous working level monitor and

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[3]Underlined numbers in parentheses refer to items in the list of references preceding the appendix.

[4]One working level is defined as any combination of short-lived daughters in 1 L of air that will result in the ultimate emission of 1.3×10^5 MeV of alpha energy. This includes the radon daughters from polonium-218 through polonium-214. The working level month is defined as the working level exposure multiplied by the hours exposed, divided by 173.

interfaced it to a microcomputer to create an alarm system, which has been successfully field-tested. It was concluded from the field test that an alarm system with expanded capabilities would be more useful to the ventilation engineer. Therefore, work began on the new system described in this report.

SYSTEM DESCRIPTION

The system investigated is a modified Senturion-200[5] manufactured by Conspec Controls, Ltd. Modifications were performed by Conspec in both hardware and software according to Bureau specifications, and the Bureau has made further hardware modifications to the system for mine use. Much of the following information was derived from Conspec manuals (9).

HARDWARE

The Senturion-200 is advertised as a "microcomputer-based real-time data acquisition, monitoring, and control system." Its basic hardware consists of a central processor, data-event printer, communication trunk, and accessors, as illustrated in figure 1. Modems may also be included with the system for long-distance operation.

Central Processor

The central processor is a desktop unit that contains the main processor, video terminal (CRT), keyboard, disk drive, and accessor trunk drivers. The main processor is a Zilog-based microcomputer system that uses a Z80A central processing unit with both parallel and serial input-output (I/O) ports. Memory consists of 65,536 (64K) bytes of dynamic

[5]Reference to specific trade names and manufacturers is made for identification purposes only and does not imply endorsement by the Bureau of Mines.

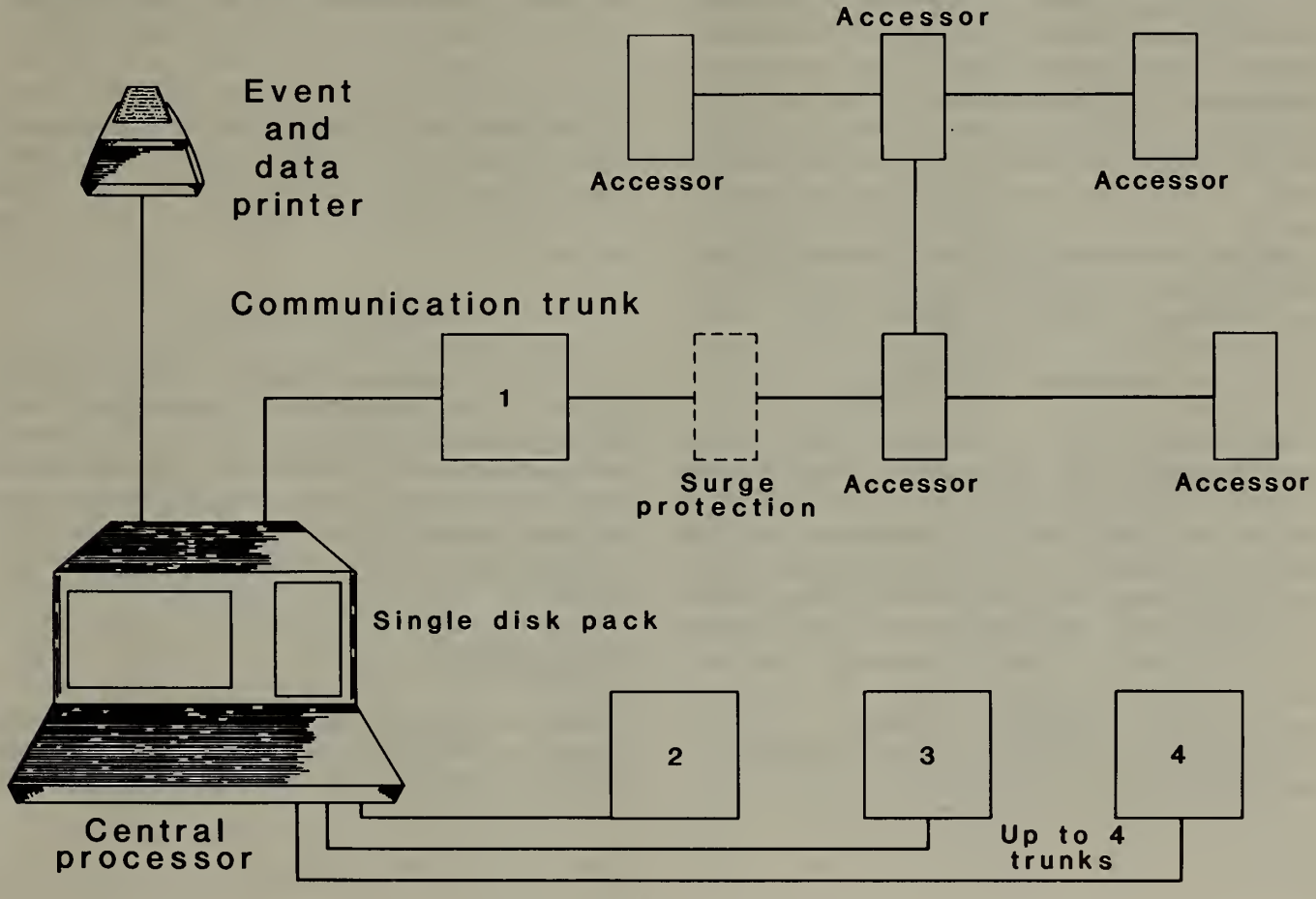

FIGURE 1. - Basic system hardware.

random-access memory (RAM), with an additional 7,168 (7K) bytes of erasable, programmable read-only memory (EPROM). A floppy-disk controller is used to interface to the system disk. Other components include direct memory access (DMA) logic, an on-board programmable read-only memory (PROM) programmer, and a four-channel counter-timer.

An Intel 8080 microprocessing unit is used to control the CRT and keyboard. The alphanumeric keyboard is similar to the keyboard of an office typewriter, with additional special function keys used to simplify operator commands when in the main program.

The system disk uses 8-in, single-sided floppy disks and provides 131,072 (128K) bytes of additional memory. Disks are used as nonvolatile storage for programs and data.

Data-Event Printer

A Teletype 43RO printer is used with the system for character-at-a-time, receive-only operation. The system is programmed for automatically and manually requested printouts. Automatic printouts are obtained for all alarms and events with their corresponding time of occurrence. The printer can also be requested from the keyboard to print descriptions, shift reports, trend logs, and other system configurations and parameters.

Communication Trunk

The communication trunk is a data channel through which the system communicates with the accessors. The trunk is connected to the central processor via an RS-232 interface and to the accessors via a single four-wire shielded cable. The trunk uses two of these wires to provide 24-V dc power to the accessors; the remaining two wires are used to transmit and receive digital signals. Trunk-to-accessor communication is asynchronous at 4,800 baud.

Accessors

Accessors manufactured by Conspec provide the interface between the system and the field devices to be monitored or controlled. At the heart of each accessor is an addressable universal asynchronous receiver and transmitter (UART) chip. This chip has an asynchronous data format consisting of a serial stream of data bits preceded by a start bit and followed by a stop bit. The UART receives two eight-bit words in a serial data stream from the processor; the first word received is an address, and the next is a command. When the address sent matches the programmed address of the receiver, the transmitter is enabled to transmit two data words consisting of accessor identity and status.

Each accessor is actually a point multiplexer with its own unique dipswitch-selectable address variable from 0 to 127. An identity (ID) dipswitch on the accessor card permits the user to select the binary word that will be used by the processor to interpret the incoming data.

Accessors are classified as either analog or binary. Both types of accessors were purchased for field testing in uranium mining situations. Table 1 is a list of accessors evaluated with the system.

Binary Accessors

Binary accessors control and/or report status from contacts. Three kinds of these accessors were used in mine tests to perform such jobs as turning on mine fans, flashing warning lights, or turning on underground alarm lights. Binary accessors used include the B1, B2, and B25 types.

B1 Accessor

The B1 accessor is used to monitor the condition of a field-mounted supervised contact. Each accessor can handle one

TABLE 1. - Accessors evaluated for uranium mining applications

Accessor[1]	Type	Data entry code	ID dipswitch 7 6 5 4 3 2 1 0
A5 (A).....	Process.....	0	0 0 0 0 0 0 0 0
A8 (A).....	Potentiometric.....	0	0 0 0 0 0 0 0 0
PI (A).....	Pulse-integrating.....	1	(2)
B1 (B).....	Single binary.....	5	1 0 1 0 0 0 0 0
B2 (BC).....	2-state commandable binary.	4	1 0 0 0 0 0 0 0
B25 (BC).....	5 output.....	7	1 1 1 0 0 0 0 0
B26 (AC).....	Setpoint (6 output).....	2	0 1 0 0 0 0 0 0

[1]Accessor classification: A = analog; AC = commandable analog B = binary; BC = commandable binary.
[2]Hardwired.

function point and receives its input from a normally closed or normally open dry contact switch. Proper installation of end-of-line resistors enables the accessor to monitor and detect sensor line faults. The contact sensor may be located up to 30 m from the accessor.

The Bureau used this accessor as a bulkhead door position monitor, ventilation fan monitor, and mine power monitor. It has also been used in conjunction with the pulse-integrating accessor (analog) to detect power interruption and sensor line faults for the continuous working level monitors.

B2 Accessor

The B2 accessor is used for command controlling of any two-state, remotely located field device. The accessor is used with a slave relay package (SRP) to interface accessor circuits with other voltages and currents. Used together, the accessor and SRP can start and stop motors, open and close dampers, or control other two-state functions. The accessor can also be used to monitor status and alarm conditions of motors not directly commanded from the terminal. When proof-of-flow status (verifying that device state matches commanded state) is required, the accessor and SRP can accommodate either an ac or dc contact switch.

In Bureau tests, this accessor was used to control underground ventilation fans from the surface. It could also be used in conjunction with a sequencing program to automatically restart fans in sequential order after a power bump.

B25 Accessor

The B25 is a commandable accessor similar to the B2, except that it can control up to five outputs. As with the B2, the accessor is used with an SRP to interface accessor circuitry to circuits having other voltages and currents. The B25 accessor cannot be used, however, to give flow status; it can only be used to turn devices on or off.

Although the B25 occupies one address, it contains five different, individually selectable points. This accessor has been used in conjunction with sequencing programs to provide a central alarm indicator in mine tests. In this capacity, it has been used to drive light-emitting diode (LED) indicators, which represent specified mine conditions such as a working level alarm. The central alarm indicator was located to provide a quick visual determination of current alarm conditions for underground personnel.

Analog Accessors

Analog accessors convert analog signals or pulses from field devices to digital form. The digitized value is then supplied to the processor upon interrogation. Four different types of these

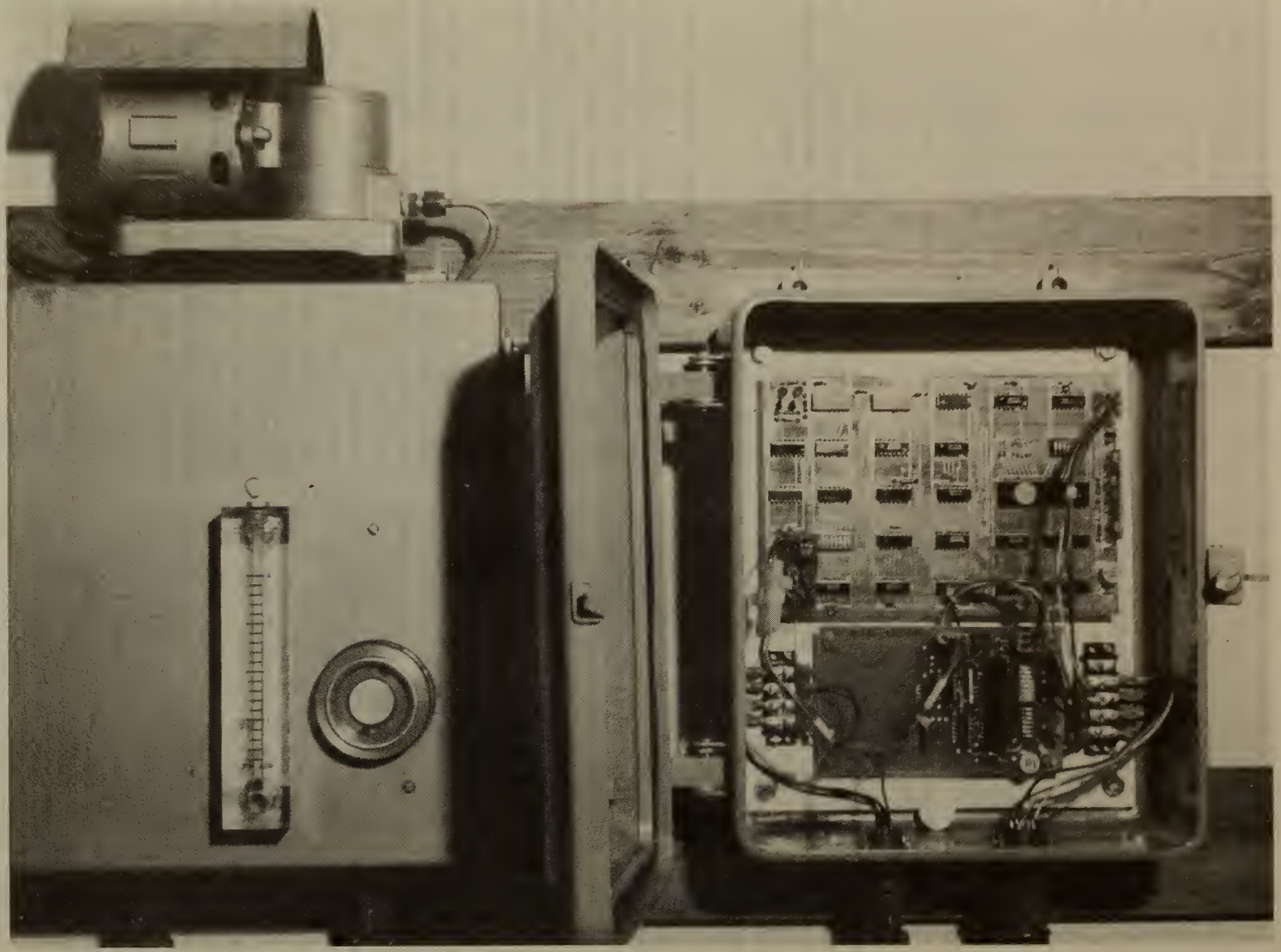

FIGURE 2. - Pulse-integrating accessor (right) and continuous working level monitor.

accessors were tested by the Bureau: A5, A8, B26, and pulse-integrating (PI) types.

A5 Accessor

The A5 is a process-type eight-bit accessor that is used with a field device to monitor the condition of a dynamic process. The signals from the appropriate sensors are converted into analog values by a process transducer. The A5 accessor will accept and digitize an analog value within the range of 0 to 5 V dc. The process transducer may be located up to 160 m from the accessor without loss of accuracy.

The Bureau has used A5 accessors with J-Tec anemometers and with temperature and relative humidity sensors.

A8 Accessor

The A8 is a potentiometric-type eight-bit accessor that is used with a remotely located potentiometric sensor. Such a sensor can be used to monitor pressures or the position of a damper or other device. This accessor can be used with any three-wire, full-travel potentiometric sensor that has a full-scale span between 2,000 and 10,000 ohms. The sensor may be located up to 160 m from the A8 accessor.

B26 Accessor

The B26 accessor is a binary setpoint accessor with a resolution of six binary bits. It is similar to the B25 (binary) except that the outputs are not individually controlled. It is classified as a commandable analog accessor. The six outputs are controlled by position and have 64 different binary combinations of enabled or disabled states. Position 0 corresponds to all outputs enabled; position 63 to all outputs disabled. This accessor can be used with other hardware logic to vary motor speeds or to adjust louvre positions.

The B26 has been used by the Bureau to provide alarm indicator lights for the PI accessor. In this application, the B26 was used with a sequence triggered by alarm conditions (such as working level, power-off, or sensor line fault) to turn on LED indicators.

Pulse-Integrating Accessors

The PI accessor card shown in figure 2 was built by Conspec according to Bureau specifications. This 16-bit accessor was designed to interface to continuous radiation monitors designed by the Bureau to measure radon and working level concentration (7, 11). These monitors output random, transistor-transistor logic (TTL) compatible pulses; the number of pulses per unit of time is proportional to radiation concentration.

A block diagram of the PI accessor is shown in figure 3. This accessor accepts the TTL-compatible pulses at a single input and divides the input pulse frequency by a selectable factor (prescaler). The prescaler is selectable from 2 to 255 and is entered as an eight-bit binary number at dipswitch S22. After being divided by this factor, the pulses are fed to a 16-bit binary counter where they are accumulated for a fixed period of time (count period). This period is selectable from 0.4 to 819 s (13 min, 39 s) in increments of 0.2 s and is set as a binary number on dipswitches S20 and S25. Weights assigned to each rocker switch are shown in table 2.

TABLE 2. - Count period dipswitch assignments for pulse-integrating accessors

Dipswitch	Rocker	Weight, s
S25.....	4	409.6
	3	204.8
	2	102.4
	1	51.2
S20.....	8	25.6
	7	12.8
	6	6.4
	5	3.2
	4	1.6
	3	.8
	2	.4
	1	.2

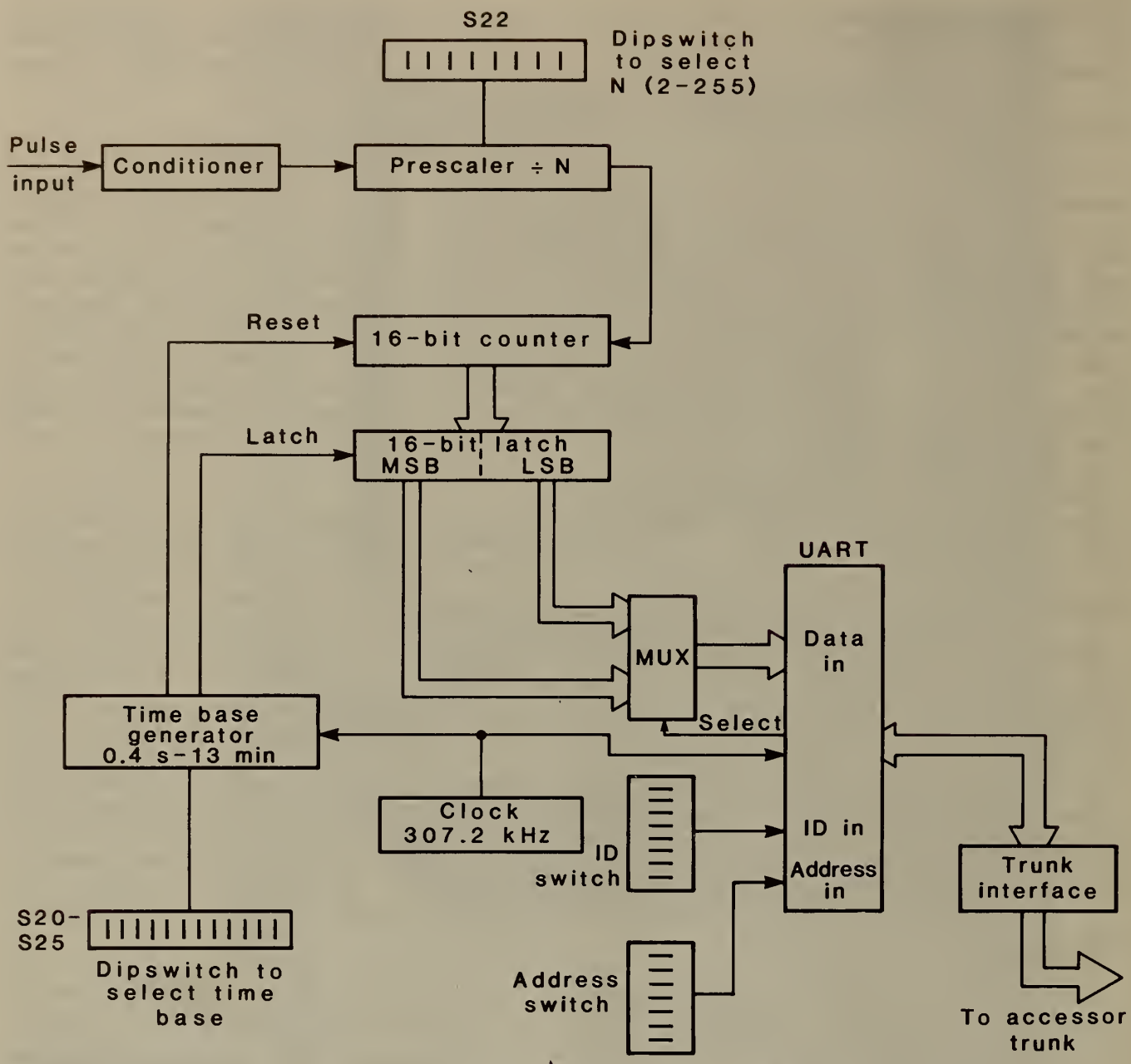

FIGURE 3. - Functional block diagram of PI accessor. (LSB = least significant byte; MSB = most significant byte; MUX = multiplexor.)

The maximum accumulated count of this accessor is hardware-restricted to the 15-bit count value of 32,767; the prescaler and count period should be selected to meet this requirement.

Two LED's located on the accessor circuit card indicate the presence of an input pulse train and count period reset, respectively. These LED's, off in normal operation, are enabled by switching rocker 8 of S25 to the on position. Troubleshooting and calibration procedures may involve the use of these LED's.

When the PI is interrogated during the scan, it will provide the processor with the last completed accumulated total. An on-board 16-bit register is used to save this last completed count. Since the data transmission to the processor is byte oriented, the processor requires two interrogations to obtain the full 16 bits of data.

The ID dipswitch of the PI accessor, unlike that of other accessors, is hard-wired and, therefore, not selectable. When this ID is received during an interrogation, the processor calls a special software routine to handle the two returned data bytes. The 8 most significant bits of the 16-bit total are then used in calculations and in alarm processing.

Modems

Points many miles away from the processor, such as those at another mine, can be monitored and controlled through modems. The modems, called long-distance accessors (LDA's), consist of a local and a remote unit. The local LDA is connected to the communications line as an ordinary accessor and requires 110-V ac power. Data transmission between this unit and the remote LDA may take place on dual, metallic-shielded, twisted-pair conductors or on a half-duplex, leased, 3,002 voice-grade telephone line. Distance limitations are as follows: up to 2.7 km with 18 American wire gauge (AWG) dual cable, and up to 6,400 facility km with the leased telephone line. Several remote LDA units can be used with a single LDA local unit.

Each message sent between modems is duplicated and slowed down to 600 baud. When receiving, the modems compare duplicate messages for errors, then increase transmission rate to 4,800 baud into the accessor trunk line. The remote LDA functions also as a remote accessor trunk by providing +24 V dc and 4,800-baud transmission to its connected accessors.

SOFTWARE

Senturion-200 software is made up of two parts: the operating system and application programs. The operating system used is a control program for microprocessors (CP/M) (10). Applications programs written by Conspec accomplish data acquisition, monitoring, and control of the various points.

Operating System

CP/M consists of programs that execute user commands and access hardware resources such as the CRT and printer. The basic system executive and boot-strapping programs reside in EPROM memory to enable the CP/M to be transferred from disk to RAM on powerup. CP/M commands consist of both resident and transient directives. Resident commands are "built in" and can be used to read the current disk directory (DIR), erase files from the disk (ERA), rename files (REN), type out contents of a file to the CRT (TYPE), and save the contents of memory as a file on the disk (SAVE).

Transient commands such as DDT, ED, MOVCPMM, PIP, SYSGEN, and XDIR are known as utilities. These have a file type of .COM and will appear in the directory if present. These commands enable the user to debug programs (DDT), create and edit files (ED), alter the CP/M image size (MOVCPMM), copy files from one disk to another (PIP), copy the CP/M boot onto new disks (SYSGEN), and look at files in alphabetical order with file size listed (XDIR).

These resident and transient commands are explained in detail in CP/M manuals.

Application Software

Once the CP/M is booted, the user can enter into application programs written by Conspec. These various programs perform in concert with each other and comprise the main program. A keyboard command (see "Startup Procedure" section) begins the loading sequence, which first alters the RAM configuration and then loads files stored on disk. For the Bureau's system, the following files are loaded:

1. S200BAS--main operating software.
2. PRN1OP--printer-operation software.
3. NLDAOP--modem-timing software.

4. SHR1OP--shift-report software.

5. RADNOP--pulse-integrating accessor software.

6. ESQ203--event-sequencing software.

After loading each of these files, the computer will display memory locations and other data. The locations correspond to slots in the startup procedure area shown on the Senturion memory map (fig. 4). When loading is complete, the main program starts and runs in a continuous loop to perform the monitoring and control functions. While in this mode, only application commands are accepted (CP/M commands are invalid).

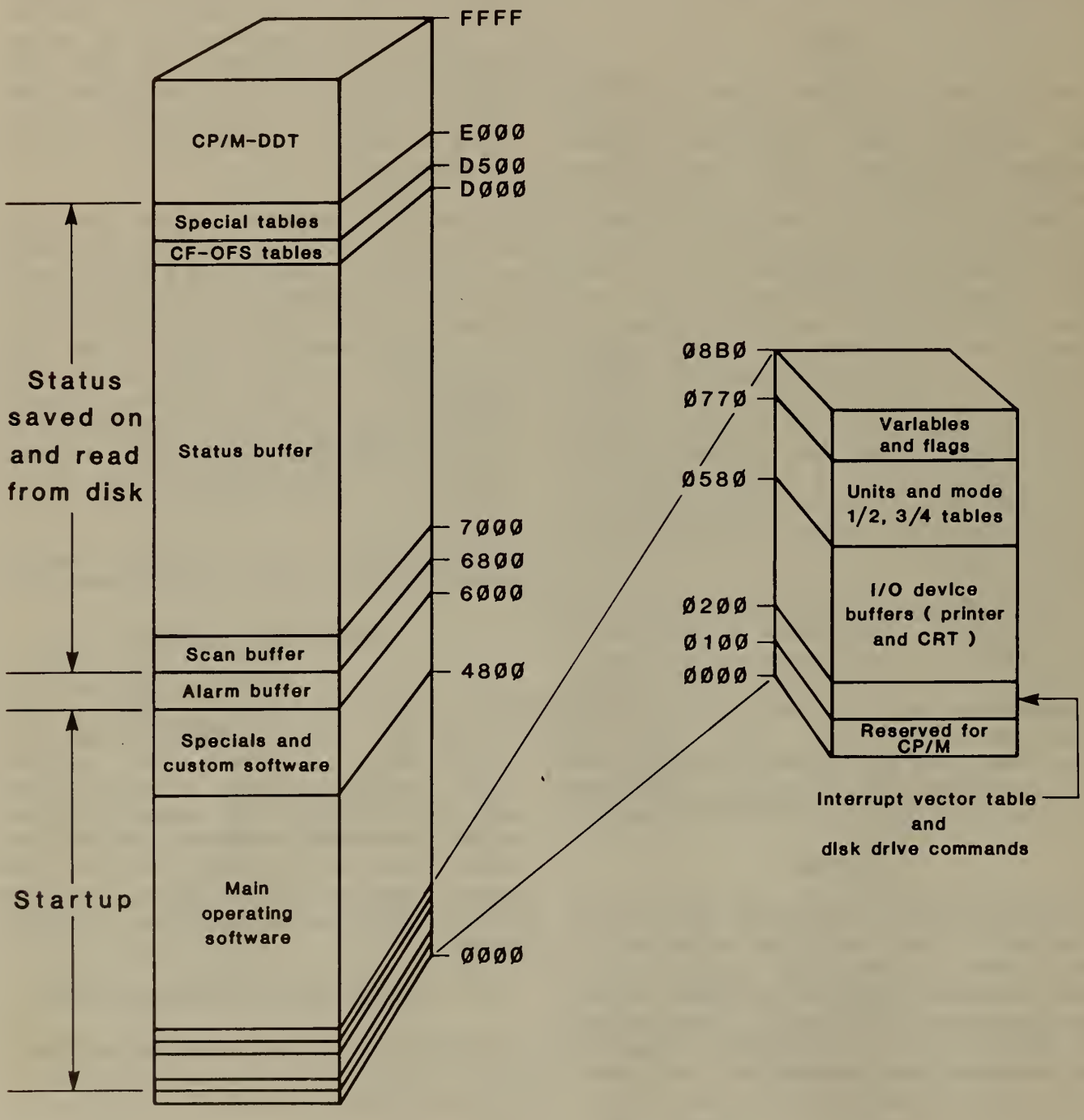

FIGURE 4. - System memory map.

Application programs include the main scan program, command service, alarm printer service, CRT display service, and other software such as the sequencing program.

Main Scan Program

Once in the main program, the processor continuously sends messages to the accessors in a predetermined sequence. Messages consist of an address and a command to which the appropriate accessor responds by returning its identity and status. Status consists of digitized information, which may represent an analog reading or the position of contacts, as shown in figure 5.

After requesting information from an accessor, the processor waits several milliseconds for data to be returned. During this time, it performs the remainder of its tasks such as updating the CRT or performing calculations. If no data are returned, as in the case of broken communication lines, a communication-fail alarm is generated. The processor then continues with the scan, starting with the next address. A flow diagram of the scan procedure is shown in figure 6. The scan checks only those accessors that the operator has enabled through the keyboard. Scan time per accessor is on the order of 10 ms; total scan time depends upon the number of enabled accessors online. The presence of modems in the system slows down the scan time.

For binary points, received data are checked against the last valid reply received. If they match, the message is ignored and no updating of status occurs. With analog points, the received data are checked for normal or alarm condition, and the delay-to-alarm counter (up to 255-s delay permitted) is updated accordingly. If there is a change in the data

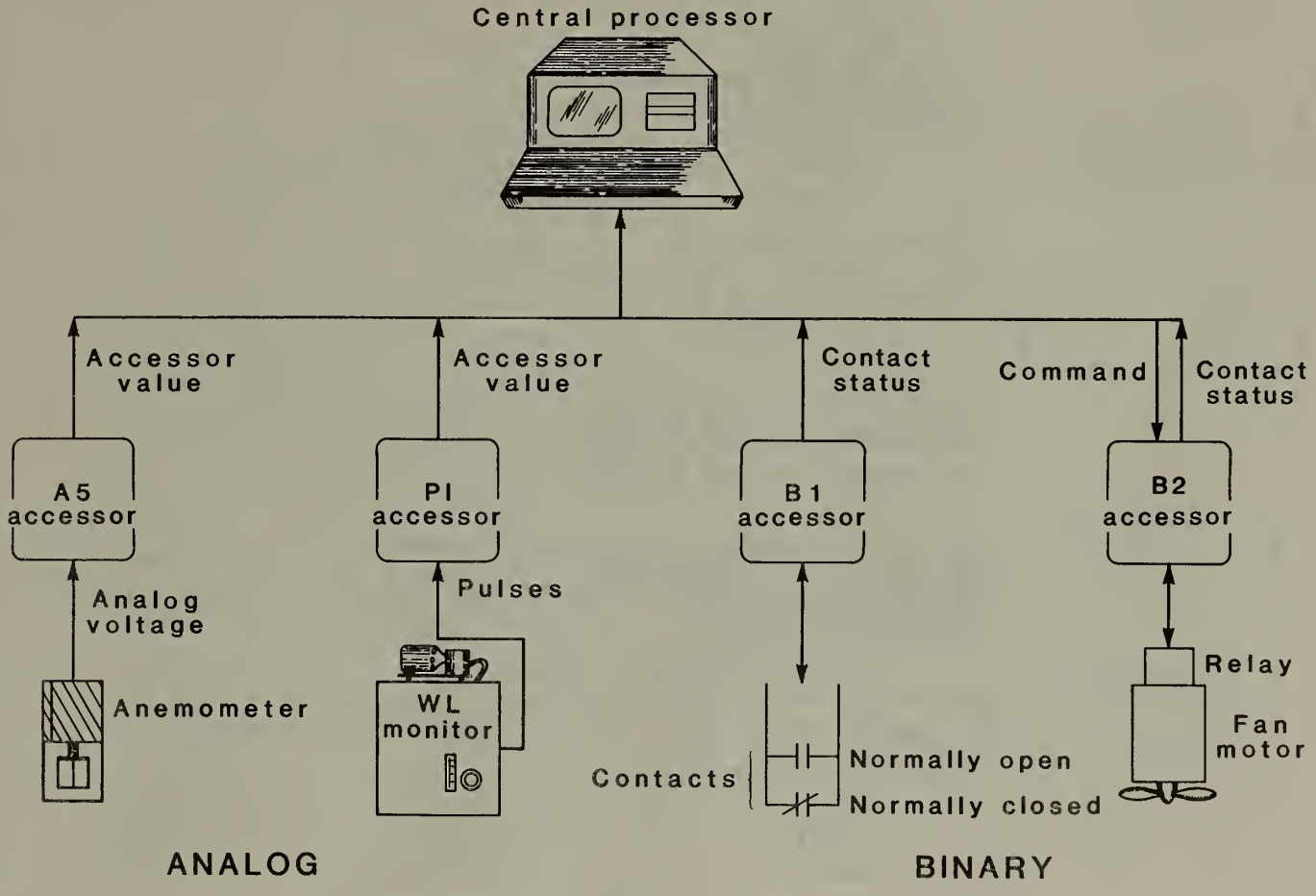

FIGURE 5. - Status from different accessor types.

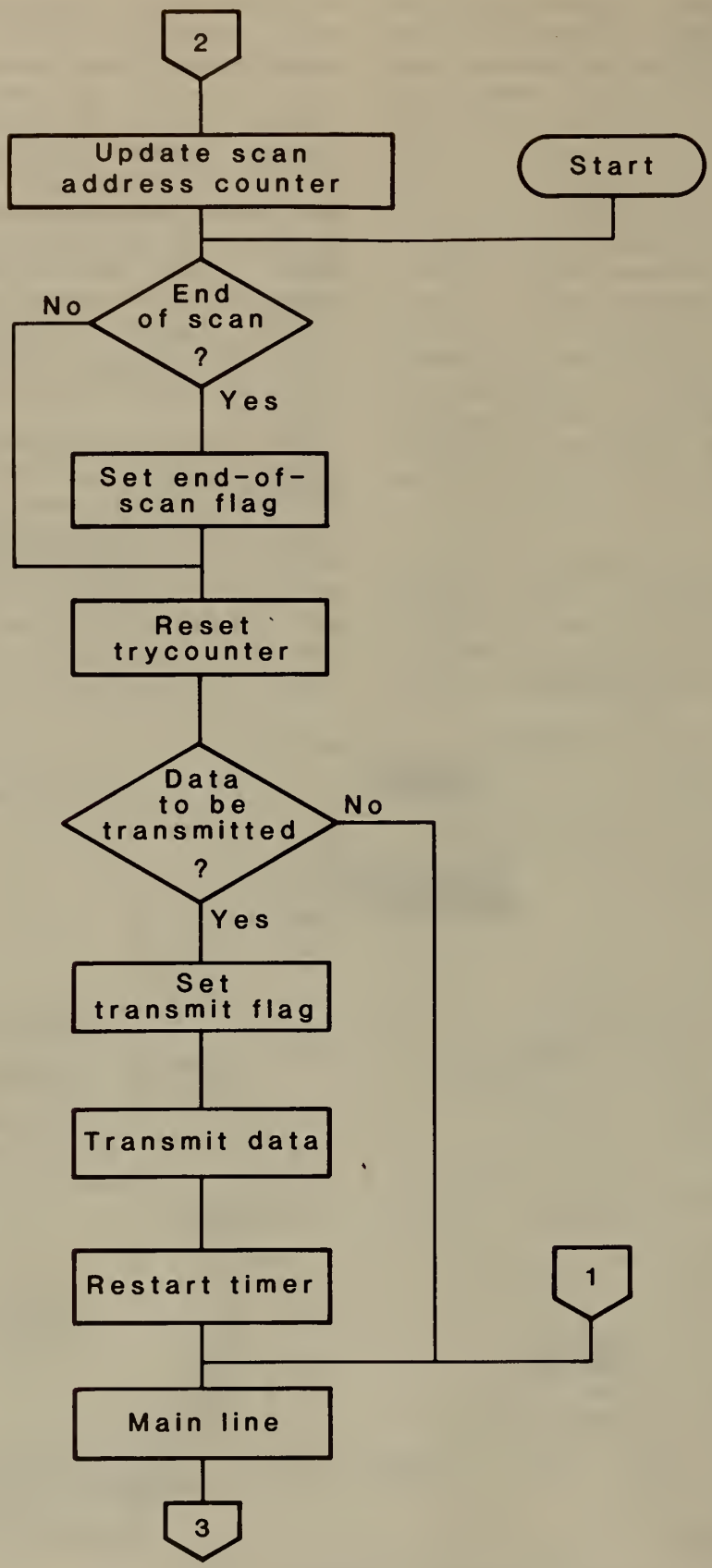

FIGURE 6. - Flow diagram of scan procedure.

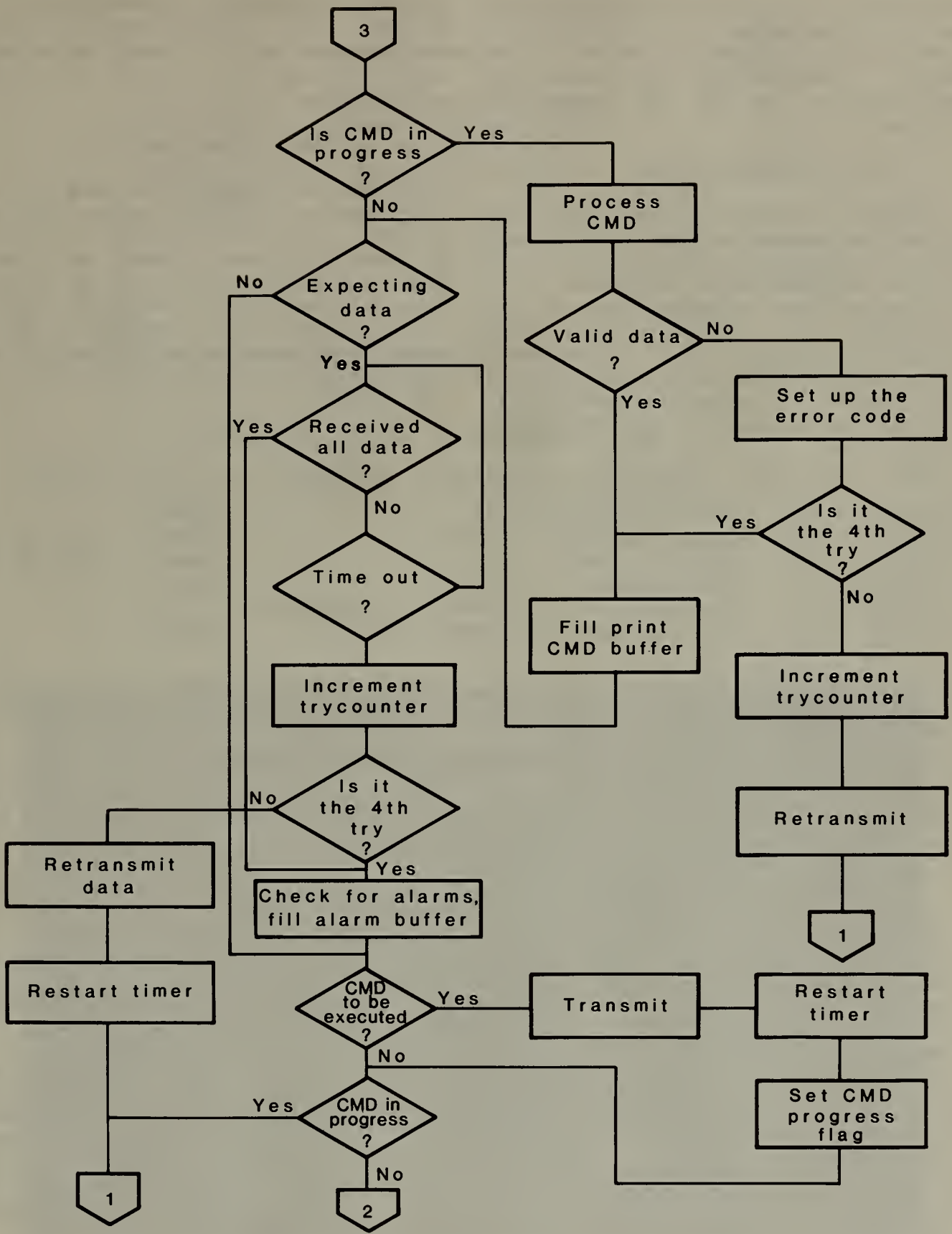

FIGURE 6. - Flow diagram of scan procedure –Continued.

received, the processor determines the nature of the change and records this information in a temporary buffer. From there, the information is decoded and displayed on the CRT and printed if desired.

Command Service

Command requests may originate from either the keyboard or from a programmed event sequence. It is possible for both to be in simultaneous operation on a time-share basis. Command requests are prioritized when issued, and a system executive processes them for priority before passing them to a command execution routine. A successful execution is printed out as an event on the printer and also displayed as a status change on the CRT. If a command initially fails, the processor will try again twice more before printing out a code of the failure on the printer.

Alarm Printer Service

The user determines at the time of data entry whether a point's events will be printed. It the print option is chosen, an occurring event (change of state) causes an internal buffer to be filled. These data are then transferred to the printer. The format observed for these messages is shown below, followed by an example printout for both binary and analog points.

TIME	PT. NO.	DESCRIPTOR	MODE 1/2	MODE 3/4	STATUS	VALUE
10:19:30	30	965 FAN MONITOR	ON		NORMAL	
11:14:01	17	WL#207 (ESCAPE)	HIGH		ALARM	1.0004600 WL
13:09:00	17	WL#207 (ESCAPE)			NORMAL	0.9923400 WL
14:00:42	1	807 COM. FAN	OFF		ALARM	
15:33:58	1	OFF		COMMD EXEC		
15:33:58	1	807 COM. FAN	OFF		NORMAL	

STATUS indicates the condition of the point and will be one of the following: NORMAL, ALARM, communications failure (C.FAIL), communications restored (C.REST), sensor lines open (SLO), or sensor lines closed (SLC). For analog points, the alarm status may have an identifier such as HIGH, LOW, or RATE.

CRT Display Service

The CRT screen is divided by software into five display areas, as shown in figures 7 and 8. Area 1 contains 12 lines reserved for critical change-of-state conditions. As these conditions occur, the processor enters the data in this area and denotes recent entries with a flashing caret (<) to the right of the data. The user may acknowledge the event by pressing the special ACK key on the keyboard, and the caret will disappear. If the event is an alarm condition, a horn may sound, which is silenced by pressing the SIL key. Since the CRT can display only 12 of these lines at a time, software provision has been made to store remaining alarms in a temporary buffer until CRT space becomes available. In this case, the cursor (*) located to the left of the events will blink. The display can be edited by positioning the cursor to any point with the UP and DOWN keys, and deleting the line with the DEL key. Waiting lines will automatically appear at the bottom of the display area. For protection, it is impossible to delete lines if unacknowledged events are present. Alarms are displayed in reverse video format (black letters on a white background) for easy identification.

Area 2 is reserved for user communication with the computer. Keyboard inputs are echoed in this area, which is also used by the processor to prompt for data entry. All invalid input is ignored by the program. User commands consist of three-character mnemonics, some of which are entered by pressing special keys.

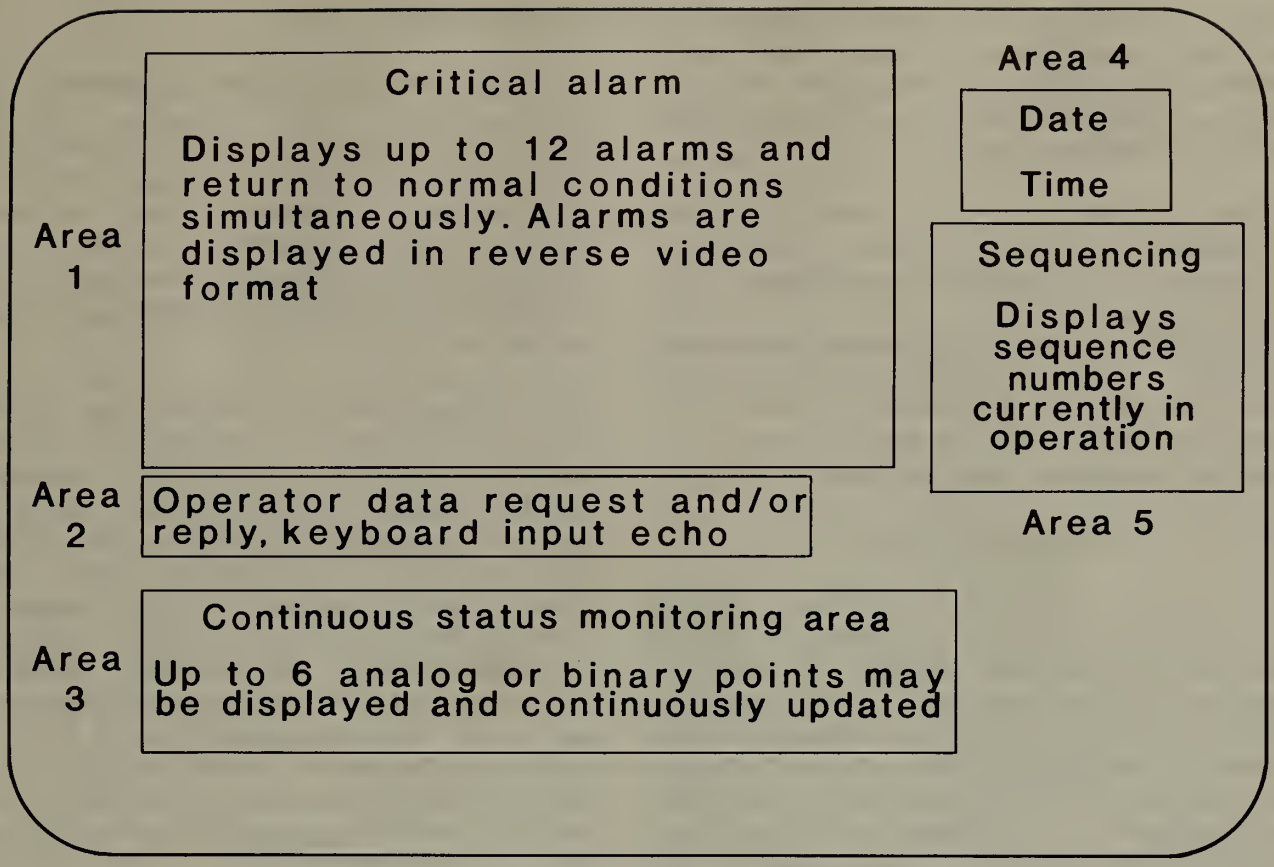
Area 1
Critical alarm
Displays up to 12 alarms and return to normal conditions simultaneously. Alarms are displayed in reverse video format
Area 4
Date
Time
Sequencing
Displays sequence numbers currently in operation
Area 5
Area 2
Operator data request and/or reply, keyboard input echo
Area 3
Continuous status monitoring area
Up to 6 analog or binary points may be displayed and continuously updated

FIGURE 7. - CRT display areas.

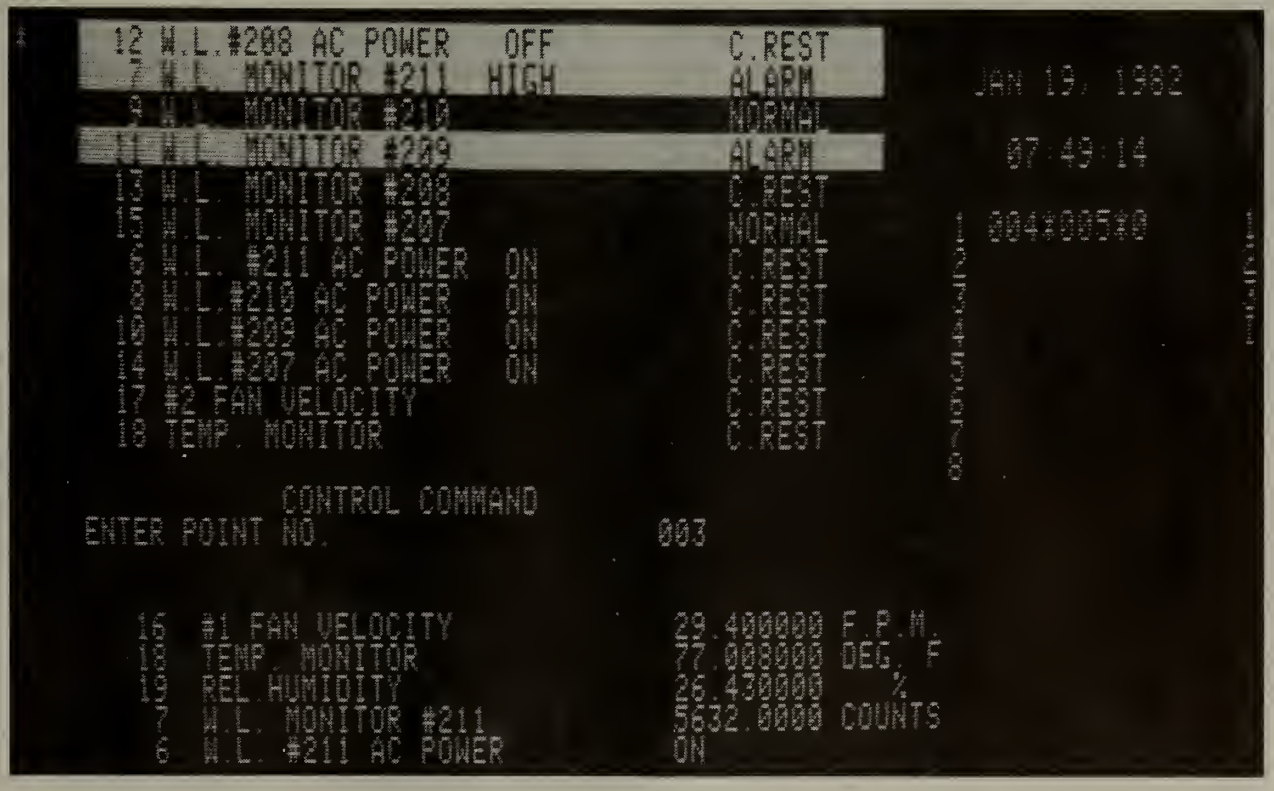
12 W.L.#208 AC POWER OFF C.REST
2 W.L. MONITOR #211 HIGH ALARM
9 W.L. MONITOR #210 NORMAL
11 W.L. MONITOR #209 ALARM
13 W.L. MONITOR #208 C.REST
15 W.L. MONITOR #207 NORMAL
6 W.L. #211 AC POWER ON C.REST
8 W.L.#210 AC POWER ON C.REST
10 W.L.#209 AC POWER ON C.REST
14 W.L.#207 AC POWER ON C.REST
17 #2 FAN VELOCITY C.REST
18 TEMP. MONITOR C.REST
JAN 19, 1982
07:49:14
CONTROL COMMAND
ENTER POINT NO. 003
16 #1 FAN VELOCITY 29.400000 F.P.M.
18 TEMP. MONITOR 77.000000 DEG. F
19 REL.HUMIDITY 26.430000 %
7 W.L. MONITOR #211 5632.0000 COUNTS
6 W.L. #211 AC POWER ON

FIGURE 8. - CRT data display.

Area 3 contains six lines reserved for monitoring continuous status. Any point chosen for display in this area will be continuously updated with current analog value or binary status.

Area 4 is serviced by a special program to display the current time and date. These are set by keyboard commands.

Area 5 is reserved for event-sequencing activity. Any sequence currently in operation will be displayed in this area; also, interrupted sequences sorted in order of priority will be noted.

Event Sequencing

The event-sequencing software allows the user to program a series of events with associated time delays. These sequences may be started either manually (with the ESQ command) or automatically. Automatic sequencing is accomplished by setting a software trigger to initiate the sequence. A trigger is a specified condition for a point; when the point changes status to this condition, the corresponding sequence is initiated by the processor. Changes of state permitted for triggering include normal, alarm, high alarm, low alarm, mode 1 (on), mode 2 (off), and communication failure. In mine situations, event sequencing has been used to restart fans after power bumps and to control LED indicators representing alarm conditions.

The sequencing software contains 255 sequence processing units (SPU's). Each SPU has the following structure:

Header (contains SPU number, priority, and hold status).

Event 1.

Event 2.

Event 3.

Link pointer (points to another SPU).

Up to eight SPU's can be in operation at any one time; when more than eight have been activated (queued), they are sorted and performed according to their priority. SPU's can be chained to any length by using the link pointer to point to another SPU.

A sequence event can be one of three types: a test, a command, or a null event. A test event within a sequence may be applied to any point in the system and is used to direct the flow of the sequence. Conditions that can be tested include normal, alarm, communication failure, and less than, equal to, or greater than a test value. Conditional jumps or calls may be chosen as a response to the test result. A jump diverts the sequence to another SPU if the test condition is false. A call performs another sequence as a subroutine when the test condition is true. Call depth is limited to four calls within prior calls.

Commands in a sequence behave in the same manner as operator commands entered through the keyboard. Although any type of accessor may be tested, only commandable accessors such as the B2, B25, and B26 types may be commanded. Time delays up to 255 s may be included with a command event.

A null event produces no action except continuation of the sequence during processing. Null events are desirable because of programming considerations.

In area 5 of the CRT display are eight reserved lines, which correspond to eight activity nodes present for sequencing. As a sequence is queued, it appears in this area in the following form:

start SPU# * current SPU# * current event#.

When all eight lines are filled with operating sequences, new sequences will be held until an activity node becomes free. A higher priority sequence will temporarily interrupt a lower priority sequence when all nodes are in use.

INSTALLATION

As part of the installation process, planning must take place to decide on sensor locations and which fans to monitor and control. The actual installation of the system in a mine typically consists of stringing the cable; installing accessors, monitors, and protection devices; and installing the main processor and associated surface equipment. Electrical checkout of the cable is necessary to ensure continuity and separation of the conductors prior to making final connections. Care must also be taken to ensure that the accessor trunk shield is tied to ground potential at only one place, usually at the central processor. Failure to do so may result in destructive ground-loop currents.

Cable should be placed along the mine back or rib in such a way as to avoid snagging by mine equipment. It is preferable not to run cable next to power or feeder cables in order to avoid stray electrical interference. Supporting strength of the cable and cable insulation type are determined by the particular application. Since accessors are designed to function within 33 pct of 19 V dc, gauge of the power wires in the cable should be chosen to minimize voltage loss due to impedance. The cable supplied by Conspec uses 14-AWG power wires and individually shielded 18-AWG data wires in an overall shield with a common drain. This cable was found to be adequate in runs up to 3 km from the accessor trunk. Voltage boosters may be used to compensate for voltage loss due to longer runs.

Accessors should be installed within proper distance limits to their field devices. Both accessors and field devices should be placed in protected areas to minimize accidental damage from personnel and equipment. Accessors used by the Bureau were housed in waterproof metal enclosures; power and communication wires entered through military specification (MS) type connectors.

Lightning protection devices should be installed where cable enters or exits mine buildings, shafts, or portals. Both primary and secondary protection are suggested by the manufacturer.

Basic surface equipment consists of a central processor, printer(s), battery backup unit, and an accessor communication trunk. Voltage regulation, noise suppression, or power conditioning devices may be required if voltage spikes are present on the 110-V ac power input to the processor. A hookup block diagram of the surface equipment is shown in figure 9.

After connecting the accessor cable to the communication trunk, voltage may be measured at each accessor to check splice connections and also to ensure that proper operation voltage is present. At this point, an accessor check diagnostic can be used to check proper operation of each accessor before starting the main program.

Once in the main program, system troubleshooting is simplified by using alarm states to diagnose problems. As an example, the Bureau often uses B1-type accessors to monitor the power and sensor line condition of continuous radiation monitors. Low alarm limits are set for a value significantly below background count. Power failure to a monitor is then an alarm condition; a low alarm without a corresponding power-fail alarm may indicate an electronic malfunction in the monitor.

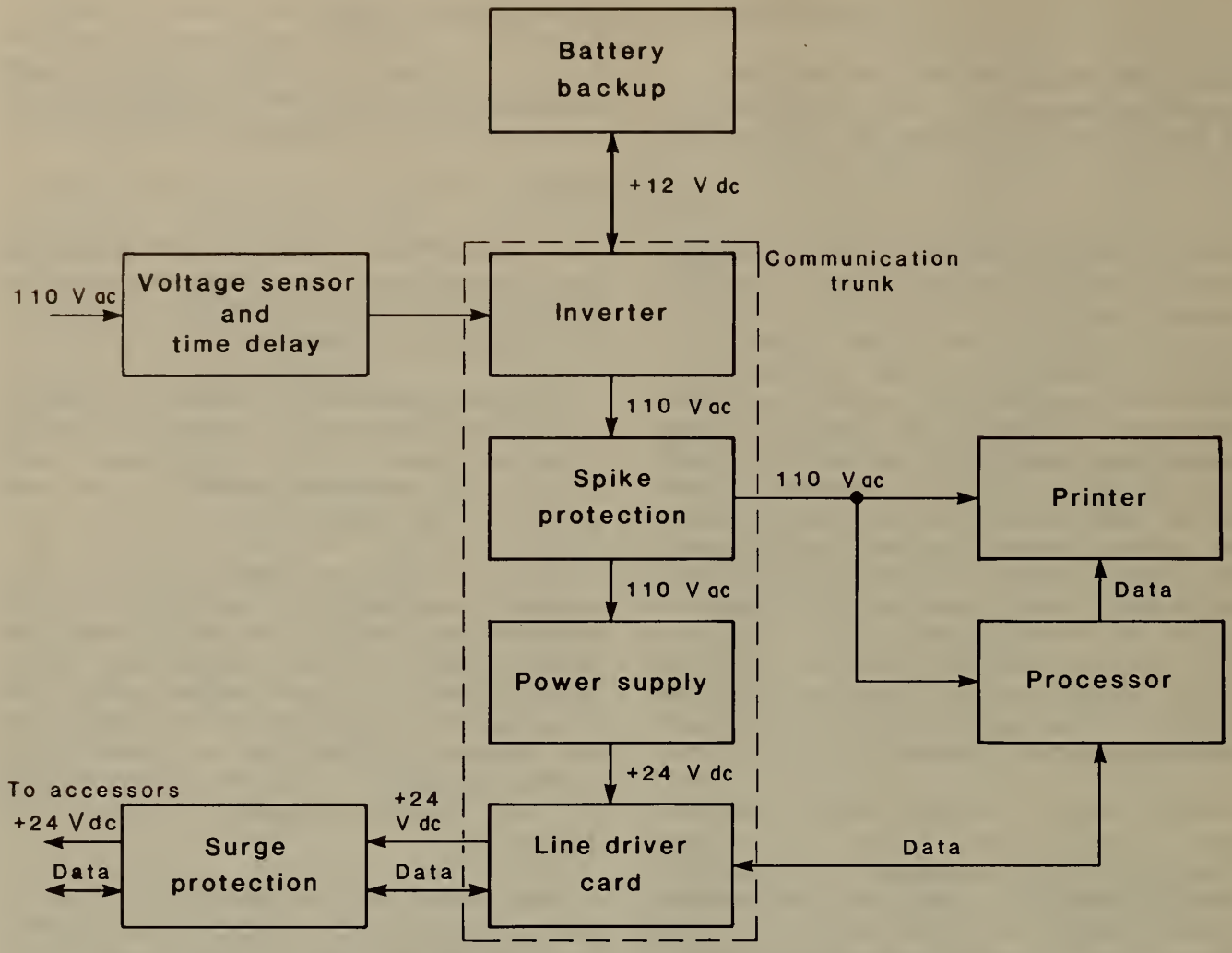

FIGURE 9. - Block diagram of surface equipment hookups.

Communication failure alarms are also diagnostic in nature. They may be caused by cable incontinuity, improper voltage to accessor, or accessor malfunction. Cable incontinuity would cause a C.FAIL alarm to be generated for all accessors downstream. This narrows the fault to the area between two accessors: the last with communication and the first without. Low voltage commonly affects certain types of accessors (B1 type) first. One may suspect recurring C.FAIL alarms on one accessor to be due to an accidentally repeated address or a possible accessor malfunction.

SYSTEM USE

After a final checkout of both surface and underground connections, the user may start the system, enter the data base, and begin operation.

STARTUP PROCEDURE

The following step-by-step procedure assumes all connections have been properly made.

1. Ensure that power is on to terminal and printer(s).

2. Turn on disk drive, insert system disk, and close drive door.

3. "Cold boot" the system into the CP/M mode by performing the following steps:

   a. Push the reset button (rear of terminal).

   b. Type the spacebar to obtain the CRT message

      MPS-92

      >

   c. Type the letter F.

CP/M will now be loaded from the disk into RAM. After loading is complete, the CRT displays

>FQCPM V1.1

A>

The A> is known as the A prompt ("A" corresponds to the disk drive designation). The computer is now waiting for further user input. The user can now either perform CP/M functions or enter into the main program mode as shown below.

4. To enter the main program mode, type

SUBMIT S

and press the return key. This will cause the main program to be loaded, a process which takes about 1 min. During this time, the CRT will display files as they are being loaded.

5. After the main program is loaded, an initialized date and time appear on the CRT in addition to the message

READ STATUS FRM DISK

OPTION (Y OR N) X (flashing)

On the first powerup after installation, probably no status information will have been stored on disk. In this case, respond "N" and press the return key. Status, or system configuration, must then be entered through the keyboard into memory before it can be saved on disk. If status has previously been saved, respond "Y" to the prompt before pressing the return key. This causes all system status to be loaded.

From this point onward, all user commands consist of three-character mnemonics typed on the keyboard and followed by the return key. After a command is entered, the computer will prompt for further data.

6. After the disk drive stops clicking, remove the disk, and turn off the drive. An access code must now be entered in order to communicate further with the computer. Two access codes are available, which permit different levels of entry: lower (operator) and higher (supervisor).

The lower level code allows the user to perform housekeeping functions oriented to system maintenance. These include editing the CRT display, editing the scan, commanding controllable points, making temporary changes in parameters, and requesting certain print routines.

The supervisor code contains the operator commands as a subset, and also allows this user to enter and delete points, control disk input and output, set up shift reports, program event sequences, and perform print routines.

After entry of the access code, an "ACCESS ALLOWED" message on the CRT notifies the user to proceed.

7. Set the time with the STT command. Present time is entered in 24-h format.

8. Set the date with the STD command. The new date and time will now be printed on the printer.

DATA ENTRY

The data base, or status, consists of all point parameters that may be saved on disk. This includes point numbers, addresses, accessor trunk number, etc., as well as sequencing programs and times for shift report or trend log generation. These data are initially entered by the user through the keyboard with data entry commands such as NEW. The NEW command is used to enter specific accessor information such as point number, accessor type, address, trunk number, announcement options, and other parameters.

Parameters that allow conversion of analog data to engineering units and set alarm limits are also entered at this time. These parameters may be updated at any time with the CAP command. With this command, old values are displayed while the computer waits for new input. Values that the user does not wish to change are retained by pressing the SKIP key.

Values for correction factor (CF) and offset (OFS) are actually entered into a memory reference table. These values may be referenced by more than one accessor. Up to 255 different CF and OFS factors may be stored in the table.

The CFI and OFS commands are used to enter values into the reference table. A data entry format must be observed. The format for correction factor (CFI command) is

M*X.XX E SX,

where M = multiplier (1, 2, or 4),

X.XX = value between 0.00 and 2.55,

E = 10 (implied), to be raised to the power of SX, and

SX = sign and exponent (-7 to +7).

The offset entry format (OFS command) is

S X.XXXX E SX,

where S = sign (+ or -),

X.XXXX = value between 0.0000 and 7.9999,

E = 10 (implied), raised to the power of SX, and

SX = sign and exponent (-7 to +7).

After data entry is completed, the DSS and PCO commands may be used to verify proper entries. Each accessor must be entered in the scan with the EDS command before the processor will initiate communication. Points can also be removed from the scan with this command for maintenance or other purposes.

OPERATION

Valid user commands are given in table 3. An (s) next to the command denotes it as supervisor-level only, and a (k) signifies that a special key also exists for that command.

TABLE 3. - System commands sorted by function

Description	Command[1]	Function
Print routines:		
Trend log.....	LTT, TREND HDG(k).	Used to enter point assignment and time period for trend log generation. Up to 10 analog points are permitted, and time period is variable from 1 to 99 min. The TREND HDG key will print a heading for the log.
Accessor scan list.	ACC.....	Produces printout of the scan list sorted by address and trunk number. This indicates which accessors are enabled in the scan.
Descriptor list...	DSS.....	Prints point numbers, addresses, descriptors, and other data.
Shift report.....	TSR(s), SPN(s), REQ.	Generates printouts of averaged values per point for up to 30 points. TSR is used to set printout times from 00 to 23 h (99 generates a report each hour). SPN assigns points to the report; REQ requests current shift report without reset of count or average.
Correction factor and offset table.	PCO(s).....	Prints desired range of correction factors and offsets in both machine and floating-point format.
Sequence programming units.	PSQ(s).....	Prints desired range of SPU's.
Sequence triggers.	STP(s).....	Prints sequence triggers by point number.
Alarm summary.....	ALS, ALARM SUMMARY(k).	Prints current alarms by point number and identifies alarm condition.
Time and date.....	TIME AND DATE(k).	Prints current time and date.
Commandable points:		
Binary point (B2, B22, B25 accessors).	COC, COMM BINARY(k).	Used to execute a mode change command on a binary point. A CRT and printer message will indicate result.
Analog point (B26 accessor).	CPA, COMM ANALOG(k).	Changes output position of commandable analog point. A CRT and printer message will indicate result.

[1]A (k) next to a command signifies that it is a special key function. An (s) denotes it as supervisor level only.

TABLE 3. - System commands sorted by function--Continued

Description	Command[1]	Function
Status file editing:		
Descriptor change.	DSE.....	Allows descriptor change of any point. New descriptor must contain 18 characters (blanks are permitted).
Analog parameter change.	CAP.....	Allows change of alarm limits, correction factor and offset reference numbers, units code, and other parameters for analog points.
Correction factor entry and change.	CFI.....	Enters correction factor into reference table. Only properly formatted correction factors are accepted.
Offset entry and change.	OFS.....	Enters offset into reference table. Only properly formatted offsets are accepted.
New accessor data entry.	NEW(s).....	Enters accessor data into memory.
Edit the scan.....	EDS(s).....	Enables or disables accessors from the scan.
Delete a point....	KIL(s).....	Removes a point from memory.
Change access codes.	EAC(s).....	Changes senior and junior access codes.
CRT display editing:		
Auto screen roll and acknowledge.	ROL.....	Automatically acknowledges and deletes old events from CRT alarm and event area to make room for display of new data.
Set time and date.	STT, STD.	Used to enter time and date in numerical format. The STD command generates a printout after date entry.
Immediate status request.	ISR, STATUS(k).	Displays immediate status of any point at the time command is issued. This display is not updated.
Clear CRT screen..	CRT.....	Clears CRT screen. Only updated data will reappear.
Continuous status monitoring.	CS1 to C26.....	Enters and deletes points in status display area on lower part of CRT.
Disk status:		
Save status on disk.	SVD(s).....	Saves current status on nonvolatile disk memory.
Read status from disk.	RDS(s).....	Loads status from disk into memory.
Format a disk.....	FMT(s).....	Formats a new disk to be compatible with system.

[1]A (k) next to a command signifies that it is a special key function. An (s) denotes it as supervisor level only.

URANIUM MINING APPLICATIONS

The computerized system investigated offers many advantages to the uranium mining industry, particularly in the use of its monitoring and control capabilities. The system requires only a four-wire cable between the main processor and the accessors to provide 24-V dc power and communication. This cable may be wired in parallel, series, or branched to allow for accessor installation over distances of up to 3 km from the central processor. Longer distances may be achieved through the use of voltage boosters and modems. Up to 128 accessors may be used per trunk line, and up to four of these lines are supported by hardware and software, for a total capacity of 512 accessors. These accessors can be interfaced to most stationary mine equipment for monitoring or control, including fans, pumps, radiation detectors, air doors, and anemometers.

The system's monitoring capabilities may be used to keep records, initiate command sequences, and assist in troubleshooting the system and its interfaces.

RECORDS

Recordkeeping is automatic for all changes of state or alarm occurrences. The operator is notified of these occurrences at the console so that remedial action can be taken if necessary. This can be applied to continuous radiation monitoring as well as to keep track of air door positions or the operational status of fans or other motors. In radiation monitoring, a rate alarm may be set to warn of rapidly changing conditions before critical exposure levels are reached. Shift reports may be used as an aid in figuring average working level exposure in monitored areas. Trend logs may be used to study radiation variation in connection with mining activity or environmental changes. Studies such as these may improve ventilation effectiveness and thereby reduce ventilation costs.

SEQUENCES

Command sequences can be constructed for either manual or automatic operation. This feature may be used to turn on, or off, a number of fans from the console in a predetermined sequence with time delays between steps. Status monitoring then gives feedback to inform the operator of command execution and if indeed the fans went to the commanded state. Anemometers interfaced to the system would give further verification of ventilation flow. In monitoring mine power with the system, the above sequence could be set to automatically start fans after a power outage. Other sequence applications include warning personnel of imminent fan or motor startups or high radiation levels, and controlling fans based on radiation readings.

Troubleshooting the system hardware (cables, accessors, and field devices) is aided by using the system's monitoring capabilities. Certain types of alarms may be used to diagnose hardware problems and to narrow down their locations. Basic hardware problems that will be detected by the system include broken trunk line, broken sensor line between accessor and field device, power failure for field devices, and certain electronic malfunctions in field devices such as radiation monitors.

CONCLUSIONS

With continually changing radon daughter concentrations present in underground uranium mines, minimizing worker exposure can be difficult. The system described in this report has the capability to continuously monitor critical situations such as fan operation and radon daughter concentrations and to alert the ventilation engineer when excessive measurements are present. It also has the capability to control ventilation, sound underground warnings, and automatically restart fans after power failures. Recordkeeping features of the system will help the ventilation engineer to control radiation hazards and to predict where future problems may occur.

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APPENDIX.--ANALOG ACCESSOR CALCULATIONS

Data returned from analog accessors, depending on the accessor type, contain either one or two bytes of digitized analog data. The computer processes these data for alarms and uses a single-precision math routine to convert to engineering units for printout and display. Initially, the user is required to calculate and enter parameters that are used by the system to determine alarms and to convert accessor values to engineering units. These parameters may be saved as status on disk and read into memory upon later startups. The basic equation used by the processor is

$$FP = R * CF + OFS, \qquad (A\text{-}1)$$

where FP = floating point value for display,

R = accessor value,

CF = correction factor,

and OFS = offset.

The accessor value is the returned data from eight-bit accessors or the eight most significant bits from pulse-integrating (PI) accessors. Because PI accessors have additional hardware factors involved (selectable count period and prescaler), their calculations are slightly different and will be covered later.

EIGHT-BIT ACCESSORS

To calculate the correction factor and offset for A5 or A8 accessors, the values to be displayed at the minimum and maximum imputs must be known. For the A5 accessor, this represents the values at 0 V dc (minimum input) and 5 V dc (maximum input). For the A8 accessor, this represents the values at 0 ohms resistance of the remote potentiometric sensor (minimum input) and 2,000 to 10,000 ohms full-scale resistance of the remote potentiometric sensor (maximum input).

Correction factor and offset are calculated from these values as follows:

$$OFS = Vmin, \qquad (A\text{-}2)$$

and

$$CF = \frac{Vmax - Vmin}{255}, \qquad (A\text{-}3)$$

where OFS = offset,

CF = correction factor,

Vmin = value to be displayed at minimum input,

and Vmax = value to be displayed at maximum input.

Alarm limits are calculated in machine units for data entry reasons. These can be obtained by substituting desired alarm limit values (for FP) into equations A-4 and A-5 to calculate for the accessor value (R) as shown below:

$$FP(L) = R(L) * CF + OFS, \qquad (A\text{-}4)$$

and

$$FP(H) = R(H) * CF + OFS, \qquad (A\text{-}5)$$

where FP(L) = floating point low alarm value,

FP(H) = floating point high alarm value,

R(L) = low alarm limit in machine units,

and R(H) = high alarm limit in machine units.

Values obtained for alarm limits, R(L) and R(H), are rounded to the nearest whole number for machine entry. An example analog calculation is shown below.

A J-Tec anemometer is to be used to measure air velocity in a drift. Since the J-Tec has an analog voltage output, it will be used with an A5 accessor. The following information is known:

1. J-Tec VA-215 anemometer output is from 0 to 5 V dc, corresponding to air velocity from 0 to 1,500 ft/min.

2. The desired alarm limits are

Low limit = 100 ft/min.

High limit = 1,000 ft/min.

Determine (1) CF and OFS and (2) alarm limits for machine entry (R values):

1. CF and OFS:

From equation A-3:

$$CF = \frac{Vmax - Vmin}{255} = \frac{1,500 - 0}{255}$$

$$= 5.88.$$

From equation A-2:

OFS = Vmin = 0.00.

2. Alarm limits:

Low alarm (100 ft/min)

From equation A-4:

100 = R(L) * 5.88 + 0;

R(L) = 17.

High alarm (1,000 ft/min)

From equation A-5:

1,000 = R(H) * 5.88 + 0;

R(H) = 170.

PULSE-INTEGRATING ACCESSORS

The following discussion pertains to a PI accessor interfaced to a continuous radiation monitor such as a radon or working level monitor.

The continuous radiation monitor outputs random electrical pulses corresponding to radiation input. PI accessors accumulate a count of these pulses for a preset time period. Accumulated pulses are converted to radiation concentrations such as picocuries per liter or working levels by the equation

$$RC = \frac{(C - B)}{T} * DF$$

$$= \frac{C * DF}{T} - \frac{B * DF}{T}, \qquad (A\text{-}6)$$

where RC = radiation concentration,

C = gross accumulated pulses,

B = background (per period T),

T = present count period,

and DF = calibration factor.

The PI accessor divides incoming pulses by a prescaler value and accumulates the result for a period of time (T). At the end of T, this result (the accessor value) is latched and supplied to the processor upon interrogation. At the end of each T, the old value is replaced by a new one.

Prescaler Value

The relationship between accessor value and actual count is

$$R = C/P, \qquad (A\text{-}7)$$

where R = accessor value,

C = count from radiation monitor,

and P = prescaler value.

Although the maximum accessor value is software-limited to 37,767, the optimum range of R in consideration of processing speed is

$$256 \leq R \leq 512. \qquad (A\text{-}8)$$

Therefore, under normal radiation conditions, the accessor will be set up so that the prescaler value is in the range

$$256 \leq C/P \leq 512$$

(desirable condition). (A-9)

Furthermore, the prescaler value must be an integer between 2 and 255, inclusive. This value is set as a binary number on dipswitch S22.

Correction Factor, Offset, and Alarm Limits

The CF and OFS values are used by the processor to convert the R value to radiation concentration (RC). Equation A-1 is used in this operation, and the floating point value to be found is RC:

$$RC = R * CF + OFS,$$

where RC = radiation concentration (floating point value),

R = accessor value,

CF = correction factor,

and OFS = offset (may be positive or negative).

By substituting with equations A-6 and A-7 and rearranging terms, a similar form can be obtained:

$$RC = R * \frac{(P * DF)}{T} - \frac{(B * DF)}{T}. \quad \text{(A-10)}$$

Therefore, for the continuous radiation monitors,

$$CF = \frac{P * DF}{T} \quad \text{(A-11)}$$

and

$$OFS = -\frac{(B * DF)}{T}. \quad \text{(A-12)}$$

The background (B) and count (C) terms in the above equations are averaged values obtained during monitor calibration.

Example PI Calculation

In this example, a calibrated working level monitor has been installed in a mine heading. The desired sample time is 5 min. The following information is known:

1. Average background count in the heading is 5,500 counts per 5 min.

2. The detector calibration factor (DF) is 6.7 E^{-4} WL-min per count.

3. The desired alarm limits are

Low limit = 2,750 counts per 5 min (one-half of background).

High limit = 1.0 WL.

Determine (1) optimum prescaler value, (2) CF and OFS, and (3) alarm limits for machine entry (R values):

1. Optimum prescaler value:

The "normal" expected radiation concentration ranges up to 1 WL; therefore, count at 1 WL is found from equation A-6:

$$1 \text{ WL} = \frac{(C - 5{,}500)}{5} * (6.7\ E^{-4}).$$

C(1 WL) = 12,962 counts.

Prescaler range from equation A-8 is

$$256 \leq \frac{12{,}962}{P} \leq 512;$$

therefore, $25 \leq P \leq 50$.

A moderate value, P = 40, is then chosen.

2. CF and OFS:

From equation A-11:

$$CF = \frac{40 * (6.7\ E^{-4})}{5} = 5.36\ E^{-3}.$$

From equation A-12:

$$OFS = - \frac{5{,}500 * (6.7\ E^{-4})}{5}$$

$$= - 7.37\ E^{-1}.$$

3. Alarm limits:

Low alarm (one-half of background = 2,750 counts)

From equation A-7:

$$R(L) = 2{,}750/40 = 69.$$

High alarm (1.0 WL)

From equation A-1:

$$1.0\ WL = R(H) * (5.36\ E^{-3}) - (7.37\ E^{-1}),$$

$$R(H) = 324.$$

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